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Reports on work done in the following areas:
- Sound radiation by instability wave packets in a laminar boundary layer.
- Plate excitation by boundary layer turbulence.
- Influence of boundary layer manipulation on wall pressure fluctuations.
- Measurement of wall shear stress.
- Surveys of structural response and dynamic wall pressure excitation.

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FUNDAMENTAL STUDIES OF HYDROACOUSTICS

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Sound Radiation by Instability Wave Packets in a Laminar Boundary Layer:

Haj Hariri and Akylas (1986) determined the sound radiated by instability wave packets in an asymptotic suction boundary layer over an infinite flat plate. The sound is "superdirective" and is beamed upstream. Haj Hariri (1987) dealt with the problem of sound radiation due to a Tollmien-Schlichting wave impinging on the trailing edge of a flat plate. This was formulated as an approximate triple deck analysis. Numerical work remains to be done to compute the amplitude and directivity of the sound. In the course of this work a new technique was developed for locating eigenvalues of the corresponding Orr-Sommerfeld problem, Haj Hariri (1988).

La Fontaine (1988) measured the amplitude and directivity of trailing edge noise. Strong forward directivity was determined. By measuring the cross-spectrum between the Tollmien-Schlichting wave velocity and the radiated sound pressure he showed the source location to be at the trailing edge.

Plate Excitation by Boundary Layer Turbulence:

Petri (1987) treated numerically the turbulence-excited response of a compliantly coated damped flat plate under significant fluid loading in order to determine the influence of the coating in alleviating the sound scattered by a line stiffener on the plate. The coating was shown to markedly reduce the acoustic scattering for both Chase and wavenumber white models of the exciting wall pressure field. He also determined that the vibratory response of the plate and the radiation field in the coating are dominated by the low wavenumber components of the turbulent boundary layer and not by the convective component.

Influence of Boundary Layer Manipulation on Wall Pressure Fluctuations:

Moller and Leehey (1989) performed wind tunnel tests with a manipulator in the shape of a honeycomb placed in the turbulent boundary layer. They showed experimentally that the manipulator reduced mean wall shear by up to 38% and RMS wall pressure by 36% over a zone extending at least 300 pre-manipulator displacement thicknesses downstream. The coherence of the wall pressure is reduced in the streamwise direction and increased in the spanwise direction by the presence of the manipulator.

Measurement of Wall Shear Stress:

Wagner and Leehey (1986) and Gur and Leehey (1989) reported on a new type of gauge developed for the measurement of mean and fluctuating shear stress on the wall beneath a turbulent boundary layer. This gauge measures the torque upon a very small cylinder located close to the wall under a shear flow. The gauge has a linear response, no hysteresis upon flow reversal, and can be made strongly directional. Spectral element calculations for Stokes creeping flow are used to correct gauge calibration for blockage effects in the cone-and plate apparatus used to test the gauge.

La Fontaine (1988) made measurements of the pressure drop across a surface fence beneath a turbulent boundary layer. These were compared with independent measurements of the mean wall shear stress. Tests were made over a very wide range of the Reynolds number R using the same gauge in both the wind tunnel and in the cone-and-plate apparatus. A linear relation was found for $R < 1$ and a three-halves power relation was found for $R > 1$.

Survey Papers:

Leehey (1988) made an assessment of the state of the art in determining structural response and reradiation due to turbulent boundary layer excitation. The need for quantitative determination of the internal impedance of the turbulent boundary layer was emphasized. More sophisticated models of the structure are also needed in order to bring out the relative importance of the low wavenumber and the convective portions of the wall pressure excitation.

Leehey (1989) surveyed the current status of theoretical and experimental studies of dynamic wall pressure. In particular he showed that the low wavenumber-frequency spectrum of wall pressure for both wind tunnel and buoyant body measurements is shown to scale best on the square of the product of Mach number and mean wall shear stress. This supports the theoretical conclusion of Landahl that fluctuating wall shear stress dipoles are a significant source of low wavenumber wall pressure fluctuations.

Publications:

H. Haj Hariri and T. R. Akylas (1986) "Sound radiation by instability wavepackets in a boundary layer," *Studies in Appl. Math.* **75**, 57-76.

H. Haj Hariri (1988) "Transformations reducing the order of the parameter in differential eigenvalue problems," *Journal of Computational Physics* **77**(2), 472–484.

P. M. Wagner and P. Leehey (1988) "A new method for the measurement of turbulent wall shear stress", Proc. 33rd Int. Instrumentation Symposium, May 1987, Las Vegas, Nevada, Instrument Society of America

P. Leehey (1988) "Structural excitation by a turbulent boundary layer: an overview ", *Trans ASME, J. Vibr., Acoustics, Stress, & Reliability in Design,* **110**(2), 220-225.

Y. Gur and P. Leehey (1989) "A new wall shear stress gauge," accepted for publication in *Experiments in Fluids.*

Technical Reports:

P. Leehey (1988) "Dynamic Wall Pressure Measurements," MIT Acoustics and Vibration Laboratory Report No. 97457-2. To appear as a chapter In Lecture Notes in Engineering - Advances in Fluid Mechanics Measurements, (M. Gad-el-Hak, ed.) Springer-Verlag Berlin, 1989.

J. C. Moller and P. Leehey (1989) "Measurements of wall shear and wall pressure downstream of a honeycomb boundary layer manipulator," MIT Acoustics and Vibration Laboratory Report No. 97457-3.

Patent applied for: P. Leehey, "Shear stress gauge," April, 1988.

Degrees granted:

Hossein Haj-Hariri (1987) "Sound radiation by instability waves in boundary layers over infinte and semi-infinte flat plates," PhD thesis, full support.

Steven W. Petri, Lt. USN (1987) "The response of line-stiffened fluid-loaded infinite elastic plates to convecting pressure fields," PhD thesis, partial support.

James C. Moller (1987) "Measurement of wall shear and wall pressure downstream of a honeycomb boundary layer manipulator," Mechanical Engineer degree, partial support.

Marvin La Fontaine (1988) "Part I: An experimental investigation of trailing-edge noise from a laminar airfoil. Part II: A study of the surface fence shear gauge," Mechanical Engineer degree, full support.

Yuksel Gur (1988) "A new type of wall shear stress gauge," MSc thesis, full support.